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UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
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BREEDING HIGH-QUALITY WILT-RESISTANT WATERMELONS

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INTRODUCTION

THE DEVELOPMENT of varieties of watermelons resistant to the wilt disease caused by *Fusarium niveum* E.F.S. has been attempted by several investigators during the past decade. It has been repeatedly demonstrated that resistance exists; that the degree of resistance increases during continued control of self-pollination; and that, in general, resistant strains developed in one section of the United States manifest resistance when grown in the field in wilt-infested soil elsewhere. Resistant varieties of diverse fruit and foliage type have been developed, but with one or two exceptions they possess inferior flesh quality when grown in California in comparison with important commercial wilt-susceptible varieties.

The need for resistant types, simulating permanent prevention of wilt, is felt both here and abroad. All temporary preventive measures so far applied have failed. As the writer[(8)3] has shown, infested soil probably remains so indefinitely; crop rotation will not eliminate the causal organism. Fertilizer treatments have been useless. Seed disinfection is of slight benefit if the soil is infested; Taubenhaus,[(18)] in fact, has stated that the causal organism sometimes invades the seed.

Custom, regional adaptation, and market preference influence the choice of varieties. Northern growers need watermelons that will mature before the first killing frost in the fall. Southern growers apparently need varieties such as Tom Watson and Thurmond Grey (fig. 1) that withstand the rough handling incident to picking, loading, and transportation. California growers demand varieties resembling the Klondike in fruit type (fig. 2), in prolificacy, and in quality as expressed by flesh texture, deep-red color, and high sugar content. In California the need for thick-rinded varieties is less acute because growers have found that Klondike fruits, if handled carefully, can be shipped as far as Canada even though the rind is thin and tender. Many California growers believe that rind brittleness ("explosiveness") indicates

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[3] Superscript numbers in parentheses refer to "Literature Cited" at the end of the paper.

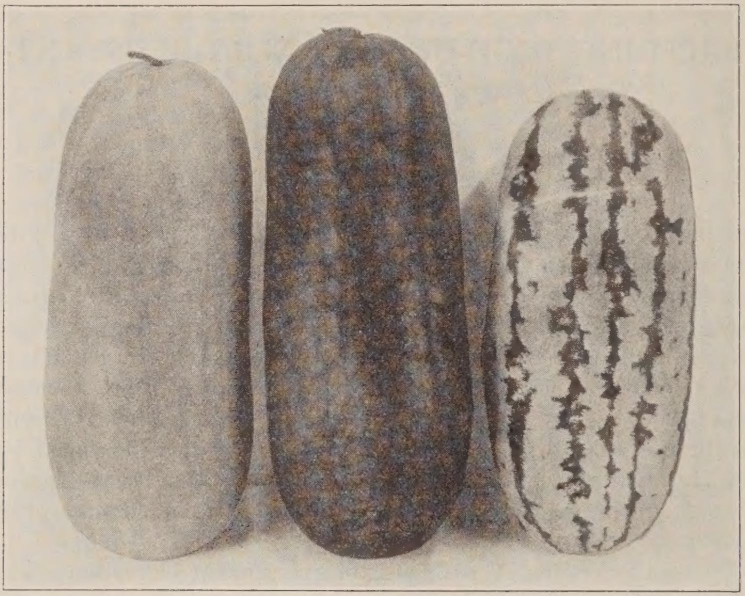

Fig. 1.—Thurmond Grey (left) and Tom Watson (center), two important varieties produced in the southern states for shipment. These are characteristically large fruited (30 to 40 pounds), with thick, tough rinds. Georgia Rattlesnake (right), formerly grown extensively, should not be confused with Striped Klondike. These varieties are seldom grown in California, but resistant strains of Thurmond Grey and Tom Watson are needed elsewhere unless growers find small-fruited, tender-rinded varieties useful.

Fig. 2.—Wilt-susceptible watermelons grown almost exclusively in California. Striped Klondike No. 11 (center) and California Klondike No. 3 on either side.

high quality. The possibility of genetic linkage of the factors governing rind explosiveness and flesh quality has not been investigated, nor the effect of environment and culture on these characteristics. Possibly, under arid climatic conditions common to the watermelon-producing districts of California and Arizona, the Klondike rind is tougher than where the humidity is high. In those western areas where the water-

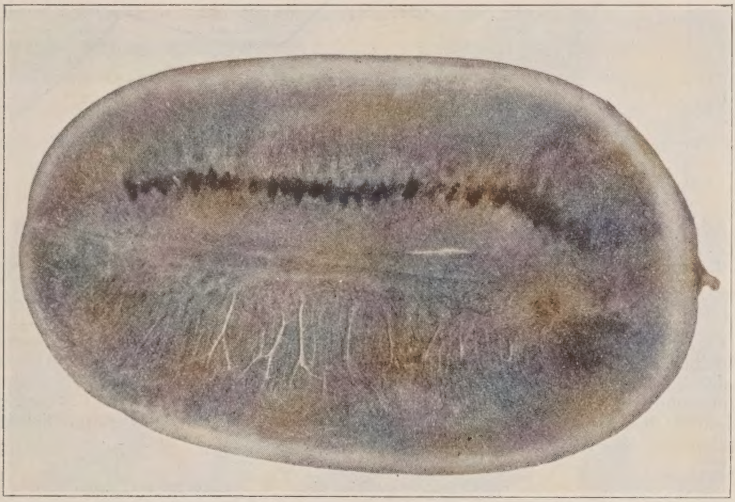

Fig. 3.—Interor view of Striped Klondike No. 11, a wilt-susceptible variety characterized by a relatively thin rind, solid, deep-red flesh, high sugar content, and agreeable texture. Klondike R7 closely resembles this variety in quality.

melon is an important crop, air temperatures during fruit maturity are probably higher than in the Middle West, the East, and the South. This high temperature might conceivably toughen the rind. At any rate Klondike, though of recognized high quality, is not yet extensively grown east of the Rockies.

Three other characteristics make Klondike desirable. First, the fruit size is consistently heavy, with uniformly firm flesh of highly desirable texture. Second, a high proportion of the total fruit weight is composed of edible flesh tissue (fig. 3). The heart flesh seldom cracks; and the amount of rind, or inedible tissue is relatively low in comparison with such standard varieties as Tom Watson, Kleckley Sweet, and Thurmond Grey. Third, as recent investigations[13] have shown, the sugar content of Striped Klondike and of Klondike is higher than that of any other varieties tested (fig. 4).

The advisability and necessity of incorporating Klondike fruit quality

Fig. 4.—Comparison of total soluble solids (determined with a hand refractometer) and total sugars (determined by chemical analysis), Davis, 1935. Striped Klondike and California Klondike No. 3 contain more sugar than Stone Mountain, Tom Watson, Thurmond Grey, and the wilt-resistant varieties Iowa Belle and Pride of Muscatine. Klondike R7, the new wilt-resistant variety described herein, is also high in sugar content.

Fig. 5.—A crop failure caused by the watermelon wilt disease in the Imperial Valley. Land once infested with *Fusarium niveum* probably remains so indefinitely. Resistant varieties such as Klondike R7 will mature a satisfactory crop on infested soil. (Compare with figure 16.)

in a wilt-resistant variety are at once apparent in California, where thousands of acres ideally suited for watermelon culture have been "wilt-sick" for many years. In the Imperial Valley (fig. 5) satisfactory watermelon soil has gradually but steadily become unavailable because of wilt infestation. In many districts in the San Joaquin and Sacramento valleys, growers have found that losses from wilt infection make production hazardous or unprofitable. A similar condition exists in many other interior districts, particularly in Riverside, San Bernardino, Los Angeles, Orange, San Diego, Napa, Butte, Colusa, and Mendocino counties. Home and market gardeners in general are now forced to obtain watermelons from districts where wilt is not yet widespread, because their own soil is infested with the organism.

PATHOGENICITY OF FUSARIUM NIVEUM[4]

Much has been written on the pathogenicity of *Fusarium niveum* during the past decade, and Wilson[(23)] has ably summarized existing information. Several symptoms have been described,[(8, 10)] modes of infection ascertained,[(8, 10, 23)] temperature relations surrounding infection and rate of fungus growth established,[(10, 16)] and variations among so-called strains of the parasite described.[(16)] More recently the relations of host to parasite have been discovered,[(10, 23)] meteorological data have been used in studies relating to the rate of infection,[(10, 11, 23)] effects of the degree of soil infestation on the rate of wilting ascertained,[(10, 23)] and the methods of indexing described.[(10, 23)]

Although these contributions have proved valuable to breeders, certain intimate host-parasite relationships seem to be not completely understood. In general, the fusaria which inhabit the vascular tissues induce marked stunting, yellowing, internal discoloration, and rather slow death of the host. *Fusarium niveum,* though capable of producing some of these symptoms, more frequently causes a sudden wilting of the foliage, often without pronounced internal discoloration of stem and roots. Why do infected seedlings in either the greenhouse or the field appear healthy just a few hours before sudden wilting and death? Why do older plants in the field suddenly die, appearing as though cut off at the soil surface (fig. 6)? Cabbage, tomatoes, potatoes, sweet potatoes,

[4] According to the latest taxonomic treatment of the Fusaria (Wollenweber, H. W., and O. A. Reinking, *Die Fusarien,* P. Parey, Berlin, 1935. 355p.) the names of the organisms referred to are now designated as follows:
F. niveum E.F.S. = *F. bulbigenum* Cke. and Mass. v. *niveum* (E.F.S.) Wr.
F. lycopersici Brushi = *F. bulbigenum* Cke. and Mass. v. *lycopersici* (Brushi) Wr. and Rg.
F. batatatis Wr. = *F. bulbigenum* Cke. and Mass. v. *batatas* Wr.
F. conglutinans Wr. = *F. conglutinans* Wr.

cotton, flax, and beans, when attacked by vascular-tissue-inhabiting fusaria, may become stunted, sometimes on only one side of the plant. They may also appear chlorotic and manifest internal discoloration, but linger

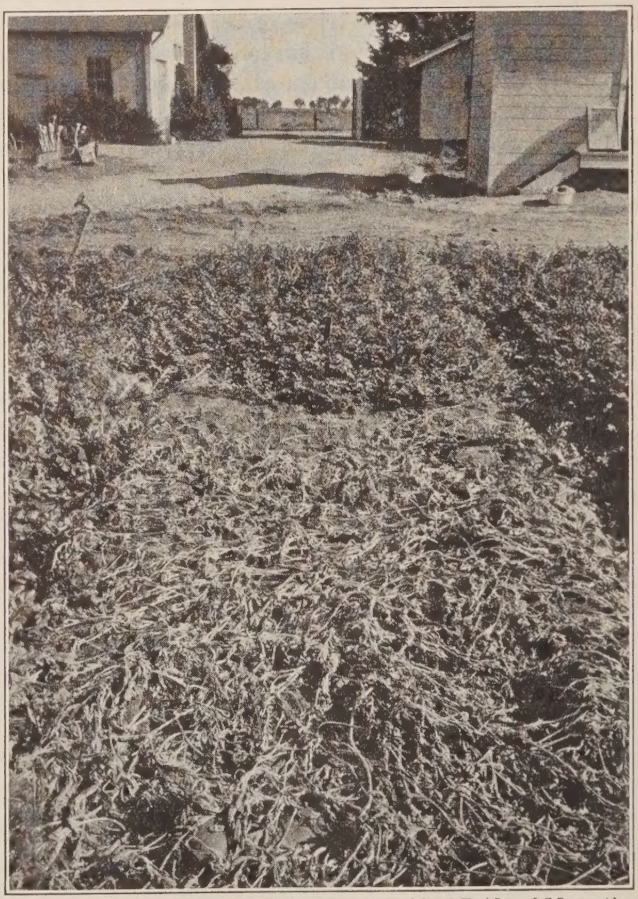

Fig. 6.—Wilted plant of C62–2–1, a hybrid of Pride of Muscatine and Klondike, photographed at 10 A.M., July 26, 1933. This plant appeared healthy three hours earlier. Such rapid wilting is common in seedling plants, but rare in resistant strains that have begun to set fruit.

sometimes for weeks, even apparently recovering late in the season. At Davis, in 1934, the writer observed apparent recovery of 200 tomato plants, all of which when examined in early August, had manifested external symptoms of the wilt disease caused by *F. lycopersici.* In the

cooler weather of September and October these plants apparently resumed normal growth; and although internal discoloration persisted, the foliage showed no symptoms. *F. conglutinans* often causes one-sided infection of cabbage, such plants often lingering for weeks before dying. The main stem of a sweet potato plant infected with *F. batatatis* may become swollen, distorted, and discolored; but again the plant may linger until killed by frost. Healthy-appearing watermelon plants, having produced a normal crop, may manifest internal discoloration but no foliage symptoms. The writer,[8] in fact, isolated *F. niveum* from healthy-appearing watermelon and citron melon plants, which subsequently lived for several weeks. Wilson[23] isolated it from seemingly healthy resistant plants that had produced their crop. With wilt-resistant watermelon varieties that have borne abundant fruit, if individual plants are examined carefully, 100 per cent internal infection may be detected; yet such plants appear outwardly healthy, and self-fertilized seed from them produces resistant progeny.

As Porter and Melhus[10] and Wilson[23] have shown, if a runner of a watermelon plant growing in wilt-free soil is induced to root in infested soil, only that portion beyond the new roots manifests infection. Also if a runner is rooted in wilt-free soil while the main root system is in infested soil, the rooted runner may remain healthy.

Having found that environmental conditions most favorable for normal plant growth were also most favorable for infection, several investigators[1, 10, 16, 23] have attempted to measure relative resistance of varieties and hybrids in the seedling stage in the greenhouse. The results, though indicating a general tendency toward agreement in field and greenhouse trials, are not yet accurate enough to be dependable.

Furthermore—in the writer's experience at least—a reliable method of determining relative resistance in the field has not been described. True, figures have appeared in print indicating per cent resistance, survival percentage, and the like. The writer has used such figures and will use them herein, but only to indicate whether or not a strain is sufficiently resistant ultimately to produce a satisfactory stand. Such records, though useful in the present breeding program, would probably prove inaccurate if used in a study of inheritance of resistance. Many plants growing in infested soil in the field die suddenly just after emergence, provided environmental conditions are favorable. Are all of them killed by *Fusarium niveum?* Cultures from such seedlings might answer this question. On alternate days we carefully count the number of plants that emerge and record the number that die, removing them from the hill. When the plants become crowded we thin to three per hill, later to

two, eventually to one. Are the plants removed during thinning resistant or susceptible? We do not know. Then how do we compute survival percentage? If we ignore the plants removed during thinning, the initial stand is automatically reduced, and the percentage of wilted plants is abnormally high. Assuming these thinned plants to be resistant, we find the survival percentage abnormally high and are not at all sure of our figures.

If thinning is delayed as long as possible, resistant strains often appear 100 per cent resistant because at the end of the season at least one plant

Fig. 7.—Breeding plot at Davis, September 1, 1934. The center plot, planted with C67–1–5–7–4, manifested 83 per cent survival, while Klondike was 100 per cent susceptible. Later selections of this hybrid were grouped and released as Klondike R7.

remains in every hill. Actually, as in the field shown in figure 7, 39 per cent of the total plants died before forming runners. Did they die because of infection with *Fusarium niveum?* Did drouth, insects, rodents, or insecticides, or soil-inhabiting damping-off organisms kill some of them? No one knows. These small plants, tender and turgid, probably die quickly from any one of several causes. In 1935, in adjacent hills of a strain consistently resistant during three previous years, the rate of seeding was varied. Twenty seeds were placed in alternate hills, and ten in the others. Without exception a higher per cent of the seedlings died where seed was sown thickly, although this strain was in the sixth generation from the original cross, had been continually grown on wilt-infested soil, and was credited with a survival percentage of 78 in 1934. In seven hills, where eighteen or more seeds germinated, seedling mortality averaged 68 per cent. Mortality in hills where an average of nine

seeds germinated was only 24 per cent. Did all these plants die because of *F. niveum?* Actually at the end of the season this strain appeared immune because no hills were missing, whether planted with ten or with twenty seeds each.

In strains that are thus sufficiently resistant to appear immune, only an occasional plant dies after runners develop. During the past three seasons, less than 1 per cent of the plants died after being thinned to two plants per hill. According to Wilson,[23] one may consider the initial stand as established after thinning, and thus ignore the plants that die soon after emergence. In certain coöperative trials, reports are received not on total wilted plants but on the number of hills in which one or more plants survive to produce a crop. The grower is concerned, not with counting the number of seedling plants that die, but with having at least one plant per hill when harvest begins. By actual count, assuming that all dead plants result from wilt infection, our most promising strains are only 90 per cent resistant.

Just why indexing of hybrids and varieties in the greenhouse in infested soil does not accurately indicate resistance observed in the field has not been satisfactorily explained, though several contributing factors have been suggested. Earlier work[10] has shown the effects of soil dosage upon the rate of wilting. In the greenhouse, with 4-inch pots, steamed soil, and disinfected seeds, a relatively slight variation in the amount of inoculum used influenced both the time and the percentage of wilting. Inoculum was so prepared as to be uniform. Wilson[23] secured similar results in naturally infested field soil, comparing susceptible Kleckley Sweet with resistant Pride of Muscatine.

The most favorable temperatures for rate of growth of *Fusarium niveum* and for infection have been determined.[8, 10, 16] Different cultures, derived from single macroconidia, have been shown to vary in rate of growth on laboratory media.[10] Such cultures vary, furthermore, in their ability to produce microconidia, macroconidia, and sclerotia; also in intensity of media pigmentation, gross growth habit, starch-digesting ability, and tendency to change the pH of culture media. Since this variability is manifested by monoconidial cultures and since such cultures may be obtained from the same field or even from the same infected plant, it is not surprising that variations in pathogenicity have been reported.[16] As Wilson[23] has clearly shown, indexing is not entirely dependable when compared with subsequent field tests. His evidence is particularly pertinent because he used F_4, F_5, and F_6 material whereas Sleeth[16] and Bennett[1] used material that was, in general, admittedly heterozygous. Some cultures used by Sleeth[16] had been in the laboratory

for several years, whereas Wilson[23] states that cultures isolated directly from the infected plant have proved more pathogenic than cultures kept in stock.

Obviously, therefore, under field conditions, plants are seldom if ever exposed to a single strain of *Fusarium niveum*. They are exposed to a "fusarial complex" as far as the pathogen is concerned and to varying soil dosages and varying environmental conditions in different localities. Until more refined technique is developed, data indicating per cent resistance and survival percentage cannot be accepted as accurate; the probable error is obviously too great. Wilson's[23] method of determining a revised stand count in the field deserves consideration. Ignoring the seedling plants that died before being thinned to two plants per hill in early July, he let his initial stand count represent the number of plants that remained after the thinning. Thus the segregates among Pride of Muscatine, Iowa King, and Iowa Belle manifested greater resistance than was evident when the entire population of wilted, thinned, and surviving plants was considered. Watermelon growers generally plant ten to fifteen seeds per hill; and even though 50 per cent of the seedling plants die enough remain for a satisfactory stand of either one or two plants per hill. With the revised stand-count method suggested by Wilson, several strains discussed herein would appear 100 per cent resistant. As Wilson,[23] furthermore, has pointed out, a more complex pathological relation exists between the host and pathogen in older plants than in seedlings; and wilting seedlings may recover under certain controlled environmental conditions. Thus innumerable factors combine to affect the host-parasite relationships.

Since relative resistance should be indicated numerically, comparative data appear in this paper. They were derived from counts made on alternate days while the seedlings were small, assuming that all wilted plants were wilt-susceptible, and that all healthy plants removed during thinning were resistant. Thus the initial stand was greater than if the thinned plants were ignored, and the survival percentage was higher in proportion. As careful tests have shown under Davis and Lodi conditions, very few plants of strains that possess appreciable resistance die after thinned to two per hill. If the thinned plants are ignored and if all dead plants are considered susceptible, many of our most resistant strains will manifest, numerically, less than 50 per cent resistance.

CALIFORNIA TESTS OF NAMED RESISTANT VARIETIES

The wilt-resistant varieties Conqueror,[5] Pride of Muscatine,[10] Iowa King,[10] Iowa Belle,[10] Leesburg,[19] Improved Kleckley Sweet No. 6, Improved Stone Mountain No. 5, and Hawkesbury[5] have been named and distributed. All these have been grown experimentally in California at various times in the past eight years, and some growers have attempted to produce Pride of Muscatine (fig. 8) and Iowa Belle (fig.

Fig. 8.—Pride of Muscatine in the sixth generation from the original selection made in Iowa in 1927. This variety is rapidly becoming obsolete, being replaced by Improved Kleckley Sweet No. 6 and Leesburg.

9) commercially. Without exception, none of these resistant varieties has manifested quality comparable with Klondike or Striped Klondike. Conceivably, under other environmental conditions, certain of them might compare favorably with Klondike or even excel it in flesh quality. The varieties Pride of Muscatine, Iowa Belle, and Iowa King develop more intense flesh color in Iowa than in California. Relative sugar content of these three varieties as grown in Iowa and California has not been accurately determined. Significantly, however, Wilson and Layton[22] at the Iowa station recognized the inferior flesh quality of Pride of Muscatine and developed Improved Kleckley Sweet No. 6 from an original selection (K-11) made in Iowa[10] in 1927. This variety has almost entirely replaced Pride of Muscatine because of superior quality and more desirable and uniform type. Likewise, the Iowa workers have attempted to improve the flesh quality of Iowa Belle by hybridization

[5] Hawkesbury is the name recently assigned by Wenholz to a wilt resistant variety previously known as Wilt Resistant Thurmond Grey.[25]

with other varieties, including Klondike. They have also used both Klondike and numerous wilt-resistant Klondike strains in their breeding work with other resistant stock. In all this work the aim has been to improve and standardize flesh quality.

Pride of Muscatine and Iowa Belle have been grown continuously at Davis since 1930. Hawkesbury has been raised since 1934, whereas the

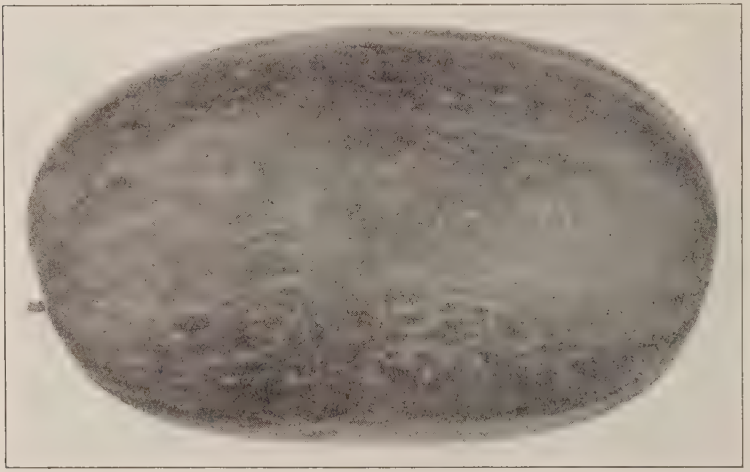

Fig. 9.—Iowa Belle, the wilt-resistant variety used in developing Klondike R7. Resistance of Iowa Belle may be traced through Conqueror to the inedible citron used by W. A. Orton.

varieties Leesburg, Improved Kleckley Sweet No. 6, and Improved Stone Mountain No. 5 were tried only in 1936. Iowa King, grown during 1930 to 1933, inclusive, was not tested further because of inferior flesh quality and unattractive appearance. The flesh color of all these has consistently been inferior to Klondike, Striped Klondike, Stone Mountain, and—usually—Tom Watson. Total soluble solids, total sugar, and sugar type have been compared for all important commercial varieties. Klondike, Striped Klondike, and the resistant California strains excel in sugar content the wilt-resistant varieties developed elsewhere, when all are grown at Davis.

Regarding resistance, accurate comparative data on survival percentages in different states are not available, for reasons previously discussed. Without exception, however, the Iowa and Australia resistant stocks have been markedly resistant on severely infested soil in California at Davis, Turlock, Lodi, Merced, Denair, Wasco, Los Angeles, and in the Imperial Valley. Resistant strains from Florida, in rather limited

tests, proved resistant at Lodi in 1933 and at Davis in 1937. Judging from this evidence and from the more detailed discussion elsewhere in this paper, pathogenic variation among various physiologically different strains of *Fusarium niveum*[16] has probably not been, to date, a serious factor in the breeding program.

Fig. 10.—Fruit of an inbred strain of the wilt-resistant variety Conqueror. Iowa Belle, a chance hybrid having Conqueror as the female parent, was used as the resistant parent in producing Klondike R7.

CHRONOLOGICAL HISTORY OF RESISTANCE TO FUSARIUM NIVEUM

Previous publications[3, 5, 10, 19] have traced the development of resistance to wilt. As pointed out in an arbitrary classification[10] of the varieties of *Citrullus vulgaris*, the varieties of group No. 1 (comprising the various types of inedible citron melons) were resistant, whereas those of group No. 2 (comprising the edible-fruited varieties) were, in general, wilt-susceptible. Concerted breeding work has changed the picture with respect to group No. 2, for we now have many edible resistant varieties.

Resistance was first demonstrated and utilized in breeding by W. A. Orton,[4] who, finding it in certain citron types, crossed one of them with the edible-fruited Eden to produce Conqueror (fig. 10). Orton stated[5] that similar work was also undertaken jointly with the North Carolina Agricultural Experiment Station to develop a variety superior to Conqueror, but apparently no results have been published. Although

Conqueror never became popular with growers, its resistance has been utilized, directly or indirectly, in developing Iowa Belle, Iowa King, and several new resistant strains discussed herein. Furthermore, since Conqueror resistance came from the stock citron used by Orton, the resistant gene or genes carried by Iowa Belle, Iowa King, and the new California strains may be traced back to this discovery.

At the Iowa station in 1926, the writer undertook to develop resistant strains by crossing Kleckley Sweet and Tom Watson with Conqueror and with various citron types from several foreign countries. Before this work had progressed far, resistance was found in individual plants of the Kleckley Sweet. This discovery seemed promising, since several generations of inbreeding of citron-Kleckley crosses would be necessary to produce resistant strains entirely free of the inedible character of the citron. Hence these resistant Kleckley Sweet selections were further inbred, a process producing Pride of Muscatine.[10] In addition, seed from open-pollinated Conqueror fruits at Lacey, Iowa, when grown in infested soil from 1926 to 1929 eventually resulted in the creation of Iowa Belle[10] and Iowa King.[10]

Walker[19] in Florida, after five years of breeding work, developed Leesburg, resulting from individual plant selection within Kleckley Sweet. Thus Leesburg and Pride of Muscatine have a similar origin. Walker's work was necessary because neither Pride of Muscatine nor Iowa Belle was suited to Florida, even though resistant there. Leesburg produces shorter fruits than Kleckley Sweet, being more blocky and consequently having less waste at the ends. It also has a tougher rind than Kleckley Sweet and compares favorably with Watson in shipping quality. Leesburg was grown at Davis in 1936, but not in wilt-infested soil. The fruits compared favorably with Improved Kleckley Sweet No. 6 and with commercial susceptible strains of the Kleckley Sweet variety. As mentioned earlier, however, Klondike, Striped Klondike, and the resistant California strains surpassed in flesh quality and sugar content any other varieties tested.

Early in 1936 the Iowa Melon Growers' Association released the resistant varieties Improved Kleckley Sweet No. 6 and Improved Stone Mountain No. 5.[6] The former resulted from inbreeding of strain K-11, isolated from Kleckley Sweet[10] at the Iowa station in 1927. It resembles Kleckley Sweet in type and proved resistant at Davis in 1936. Improved Stone Mountain No. 5 resulted from crossing Stone Mountain (suscep-

[6] Described in Iowa Agricultural Experiment Station Annual Report for 1935 as Improved Pride of Muscatine and Iowa Dixie, respectively. These names are now obsolete.

tible) with a resistant, round-fruited, yellow-skinned, edible, white-fleshed Japanese variety designated as Japan No. 7.[10] Although edible, the flesh of Japan No. 7 was not crisp. At Davis in 1936, Improved Stone Mountain No. 5 was resistant; but its quality was decidedly inferior to the ordinary, susceptible Stone Mountain variety in flesh texture, color, and sugar content.

Varietal trials in Australia described by Wenholz[24, 25] have demonstrated the resistance of a dark-seeded strain of Grey Monarch. This new

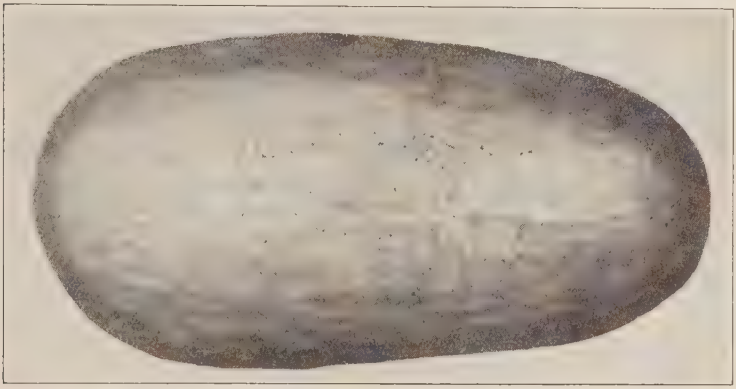

Fig. 11.—A fruit of a wilt-resistant selection within the variety Grey Monarch (white-seeded). Except for seed color, this strain closely resembles Hawkesbury, brought out in Australia.

variety has been resistant at Davis and has recently been named Hawkesbury. It is extremely prolific, producing relatively small fruits (25 pounds) that resemble Thurmond Grey in shape and skin color but differ in being smaller, having paler flesh color, lower sugar content, and darker-colored seeds. These characteristics probably indicate that this new resistant variety is a selection from the ordinary Grey Monarch, which produces white seeds. The writer, in fact, in 1930 isolated a strain of the white-seeded Grey Monarch (fig. 11) that was resistant but so inferior in quality that further breeding work was not attempted. The Hawkesbury, being resistant and similar in fruit type to Thurmond Grey, should prove valuable in a breeding program with the latter. Very possibly this variety, even in its present state of development, may prove adapted to certain districts. The origin of these resistant varieties is indicated in table 1.

TABLE 1

SUMMARY OF THE DEVELOPMENT OF WILT-RESISTANT WATERMELON VARIETIES

Variety	How developed	Agency	Originator	Year originated	Bibliography reference number
Citron	Naturally resistant, inedible types	United States Department of Agriculture	Orton	1903	4
Conqueror	Citron × Eden	United States Department of Agriculture	Orton	1911	5
Iowa Belle	Chance cross of Conqueror with unknown variety	Iowa Agricultural Experiment Station	Porter and Melhus	1929	10
Iowa King	Chance cross of Conqueror with unknown variety	Iowa Agricultural Experiment Station	Porter and Melhus	1929	10
Pride of Muscatine	Selection from Kleckley Sweet	Iowa Agricultural Experiment Station	Porter and Melhus	1929	10
Japan 7	Naturally resistant variety from Japan	Iowa Agricultural Experiment Station	Porter and Melhus	1929	10
Hawkesbury	Selection from Grey Monarch	New South Wales Department of Agriculture	Wenholz and Shirlow	1936	24
Leesburg	Selection from Kleckley Sweet	Florida Agricultural Experiment Station	Walker	1936	19
Improved Kleckley Sweet No. 6	Selection from Kleckley Sweet	Iowa Agricultural Experiment Station	Department of Botany and Plant Pathology	1936	
Improved Stone Mountain No. 5	Japan 7 × Stone Mountain	Iowa Agricultural Experiment Station	Department of Botany and Plant Pathology	1936	..
Klondike R7	Iowa Belle × Klondike	California Agricultural Experiment Station	Porter	1937	Present paper

THE DEVELOPMENT OF RESISTANT VARIETIES FOR CALIFORNIA

The discussion above indicates the need in California for resistant varieties resembling the Klondike in type and quality. Dr. J. T. Rosa, from 1923 until his untimely death in 1928, attempted to secure resistance by selecting within Klondike and by using both Conqueror and various citron types as resistant parents in crosses with Angeleno, Chilean, and Klondike, the three most important varieties in California at that time. The writer, testing certain of Rosa's strains in 1930 and 1931, found the citron hybrids resistant but extremely variable in type and decidedly inferior in quality. None of Rosa's Klondike selections nor of his hybrids involving Conqueror appeared at all promising as resistant material.

A new program of selection, hybridization, and varietal testing was accordingly inaugurated. Since adequate infested soil was not available at the station, a severely infested acreage was secured at Lodi, in the San Joaquin Valley. Many years ago the Lodi district enjoyed an enviable reputation for its high-quality watermelons. By 1930, however, production in this district was confined to small tracts not previously used for the purpose. The field chosen for the breeding work had been planted with watermelons in 1929, but less than 2 per cent of the plants survived. Investigations were continued at Lodi until 1934. By that time adequate infested soil was available at Davis on University property. Since 1930, outlying tests have been conducted with growers in every important watermelon district of the state.

Selection within Commercial Varieties.—Beginning in 1930, seed of all available edible varieties not previously tested by the writer in Iowa was obtained and planted at Lodi. This procedure served a twofold purpose. Possibly varietal resistance existed; and possibly, considering the success in isolating Pride of Muscatine from Kleckley Sweet, resistant plants of certain susceptible varieties might be found. During three years no naturally resistant edible-fruited varieties were discovered.

Resistant plants were found, however, in the varieties Klondike and Grey Monarch. From an initial stand of sixty-eight Grey Monarch plants, only two survived in 1930; and self-fertilized seed was obtained from only one. As indicated earlier, pale flesh color and low sugar content combined to lower the value of this selection except as a parent for hybridization. Its skin, furthermore, was yellow, whereas green-skinned varieties are demanded in California. By continued inbreeding, a strain of this variety manifested 68 per cent resistance in 1933.

In 1930, 10 pounds (approximately 100,000 seeds) of Klondike seed was planted at Lodi. The initial stand of seedlings was not recorded; but

by August 15 all plants of this variety were dead. In 1931, 10 pounds of Klondike seed was again planted at Lodi, and sixteen plants lived to produce mature fruits. Thus, from approximately 200,000 seeds of this variety, only sixteen plants survived infection with *Fusarium niveum*. Unfortunately, self-fertilized seed was obtained from only nine plants; and although open-pollinated seed was harvested from the other seven, subsequent tests proved such seed valueless as a source of resistance.

Of the nine resistant Klondike plants the progeny of only one, after two years' trial, seemed worthy of further propagation. Even this progeny, designated as pedigree 24, is not a typical Klondike. At present it is in the sixth inbred generation from the original selection and, though remarkably uniform with respect to desirable fruit type, flesh color, and sugar content, it has undesirable flesh texture. Its resistance has been demonstrated in California, Iowa, Florida, Georgia, Virginia, and Indiana. In Georgia and Florida its texture is less objectionable than under California conditions. Its rind, furthermore, is tough, although thin, and will withstand rougher handling than Klondike or Striped Klondike. Fruit-skin sutures are usually indistinct; the skin is deep bluish green and exceedingly attractive. For three years the writer has considered releasing it as Klondike R16; but the number of watermelon varieties is already excessively large. One more, unless really of outstanding merit, merely complicates the situation. The present pedigree of the best strain of this selection, incidentally, as referred to in certain tables in this paper, is 24–31–1–6–3–10. It was sampled out to various station coöperators and seedsmen for trial in 1936 as strain No. 2, and in 1937 as No. 8. If it is released, its varietal name will be Klondike R16, the letter R indicating resistance to *Fusarium* wilt. Typical fruits of this strain are shown in figure 12.

Somewhat different procedure designed to isolate resistant Klondike strains by straight selection was followed at Davis in 1930. Seed of commercial Klondike was secured from eight seed companies. The eight lots were thoroughly mixed for a composite sample. Three thousand seeds were planted in $4 \times 4 \times 4$-inch plant cups in the greenhouse on March 28, the soil being prepared as follows: naturally infested field soil was placed in the lower half of each plant cup, and the cups were then filled with steamed soil. This practice was designed to minimize loss caused by seedling rot and damping-off. Although *Fusarium niveum* may induce these two symptoms in seedlings, the infested soil probably contained other damping-off and seedling-rot-producing organisms, which might lower emergence rate and percentage.

Of these seeds, 93 per cent germinated, producing 2,790 plants. Wilted

seedlings were pulled as they appeared, until on May 26 only 81 plants remained, representing approximately 4 per cent of the initial stand. These were transplanted into the field but into wilt-free soil. Plants continued to die from wilt during the summer, many flowers were self-pollinated, and on October 10 there were twelve living plants, all of which matured self-pollinated fruits.

Seed from these twelve plants was planted in infested soil in the field at both Davis and Lodi in 1931 and 1932; but at both places all the plants

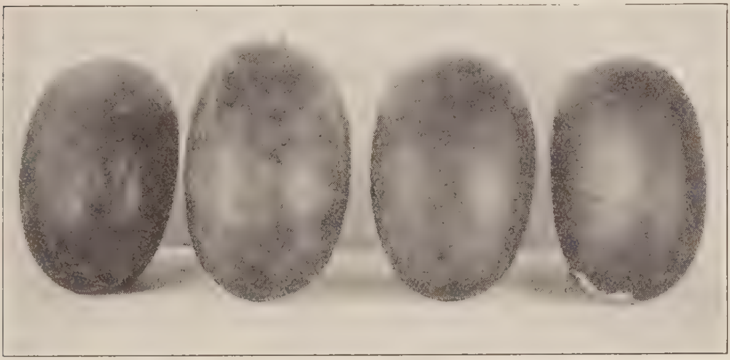

Fig. 12.—Klondike R16, resistant to wilt but not yet released to the trade. In type and size it resembles Klondike R7; but the sutures are less distinct, the rind thin but tougher, and the flesh undesirably firm. This strain responds well in the southeastern states.

died from wilt before maturing any fruit. Apparently this technique was faulty, and probably the seedlings should have been transplanted from the greenhouse into infested field soil in 1930.

This attempt was repeated in March, 1931; but the surviving seedlings were transplanted into infested instead of disease-free soil in the field. Among 3,268 seedling plants in the greenhouse only 62, or approximately 2 per cent, were alive when the plant cups were removed to the field on May 14. Plants continued to die during the summer; but self-fertilized seed was secured from all the living plants, seven in number, on October 8.

This seed was then planted in infested field soil in 1932. Of the seven strains, three were completely susceptible, but the other four manifested slight resistance. Self-fertilized seed from these produced moderately resistant strains in 1933. Continued inbreeding of resistant plants was continued until 1935, when maximum resistance of strain 3 (an arbitrary designation) was approximately 82 per cent. Since strain 3 was decidedly inferior in quality to the strain referred to earlier as Klondike

R16, it is now being used only as the resistant parent in other crosses. The development of this strain, however, demonstrates again that resistance may be obtained by selection within commercial varieties. Thus Porter and Melhus[10] and Walker,[19] respectively, developed the varieties Pride of Muscatine and Leesburg. Improved Kleckley Sweet No. 6, Hawkesbury, the resistant Klondike known as R16, and also the resistant White Seeded Grey Monarch were all developed in this way.

In this connection the following comment is pertinent. Since relative resistance gradually increases during continued inbreeding of selected strains and since resistance is recessive in all crosses thus far reported, resistance is probably governed by more than one factor.[1, 15] Where it is due to a single factor difference, being inherited as a recessive, then complete resistance would be manifested by the immediate progeny of a selfed plant of a commercial variety that withstood the fungus. No such case has come to the writer's attention.

Until proper technique is developed, furthermore, the exact mode of inheritance of resistance can probably not be demonstrated. The question was discussed in more detail earlier in this paper.

Hybridization.—Contemporaneously with the straight selection work just described, a hybridization program was initiated. Citrons and the following varieties were used as resistant parents: Conqueror, Pride of Muscatine, Iowa Belle, and Iowa King. These resistant varieties were crossed with various commercial Klondike strains as well as with inbred Klondike strains of the Rosa collection. Soon Iowa Belle, despite its peculiar and rather unattractive skin color, proved the most valuable of the resistant parents. Accordingly, further breeding of hybrids involving the other sources of resistance has been discontinued. Wilson[23] has also valued Iowa Belle highly as a parent in transmitting resistance to originally susceptible sorts.

Many crosses were made with different Iowa Belle plants growing in infested soil as female and with numerous plants of the Klondike variety as male parents. Cross 67 soon manifested marked superiority of resistance and type.

Several F_1 plants of C67 grown in the greenhouse during the winter of 1930–31 yielded self-fertilized seed. The F_2, F_3, and F_4 generations were grown in infested soil at Lodi from 1931 to 1933, inclusive. The F_5, F_6, and F_7 generations were grown in infested soil at Davis from 1934 to 1936, inclusive. Three of the most uniform, similar, resistant, and highest in quality of the F_8 lines of the 1935 crop were planted together in 1936; and the resulting seed was distributed to California growers and California seed producers in February, 1937, as Klondike

TABLE 2

CONDENSED HISTORY OF THE KLONDIKE R7 WATERMELON

Year	Place grown	Actual pedigree	Generation	Per cent survival*	Average fruit weight, pounds	Average fruit-shape index	Average per cent soluble solids	Rating score†
1931	Lodi	C67-1	F_2	20.3	26.5	742	....‡	1.8
		C67-1, plant 5		....	21.0	808	....‡	3.3
1932	Lodi	C67-1-5	F_3	56.1	21.6	633	‡	1.8
		C67-1-5, plant 7			22.0	643	‡	3.1
1933	Lodi	C67-1-5-7	F_4	63.4	16.4	587	11.3	2.1
		C67-1-5-7, plant 4		....	21.0	593	11.6	4.0
1934	Davis	C67-1-5-7-4	F_5	83.6	21.4	615	11.7	2.9
		C67-1-5-7-4, plant 10		....	20.5	649	11.7	4.0
1935	Davis	C67-1-5-7-4-10	F_6	87.1	19.0	619	10.8	3.1
		C67-1-5-7-4-10, plant 9¶		....	26.0	648	11.5	3.5
		C67-1-5-7-4-10, plant 7¶		....	16.0	636	11.4	3.4
		C67-1-5-7-4-10, plant 3¶			27.0	594	10.9	3.6
1936	Davis	C67-1-5-7-4-10-9	F_7	90.0	18.2	678	10.9	3.3
		C67-1-5-7-4-10-9, plant 6		....	22.0	621	11.0	4.0
		C67-1-5-7-4-10-9, plant 19		....	21.0	614	11.6	3.5
		C67-1-5-7-4-10-9, plant 18		....	20.0	607	11.2	4.0
		C67-1-5-7-4-10-7		84.8	18.9	643	11.5	3.2
		C67-1-5-7-4-10-7, plant 20		....	20.0	643	12.2	3.8
		C67-1-5-7-4-10-7, plant 10		....	20.3	654	11.0	3.6
		C67-1-5-7-4-10-3		83.0	18.6	718	11.2	3.3
		C67-1-5-7-4-10-3, plant 12		....	18.0	679	12.8	3.5
		C67-1-5-7-4-10-3, plant 19		....	18.0	700	12.9	4.0
		C67-1-5-7-4-10-3, plant 1		....	24.5	678	11.0	3.5

* For reasons discussed in the text these percentages are not an absolutely reliable index of resistance. In 1935 and 1936, delayed thinning until all susceptible plants died resulted in a perfect stand, indicating complete resistance late in the season, whereas some seedling plants were lost because of wilt infection.

† Based on all fruit characters and 4 is a perfect score. Note the slow but consistent improvement from F_2 to F_7, remembering that these data were on resistant plants only, since susceptible plants died before maturing fruit.

‡ Soluble solids not determined.

¶ Seed from plants thus indicated was grouped; and the seed from the resulting crop was released in February, 1937, as Klondike R7.

TABLE 3

DIFFERENTIATING CHARACTERISTICS OF CERTAIN WILT-RESISTANT AND WILT-SUSCEPTIBLE WATERMELONS AT DAVIS IN 1936

Variety	Pedigree	Number of generations inbred	Reaction to wilt	Fruit charaters								
				Skin color	Sutures	Average weight, pounds	Average fruit-shape index	Flesh texture	Flesh color	Soluble solids, per cent	Rating score	Comment regarding defects
California Klondike	Strain No. 3	11	Susceptible	Green	Pronounced	18.2	587	Excellent	Red	11.1	3.5	Tender rind
Striped Klondike	Strain No. 11	5	Susceptible	Striped	Absent	23.8	601	Excellent	Red	11.5	3.6	Acceptable
Iowa Belle		8	85 per cent resistant	Mottled	Very faint	25.5	536	Fair	Pink	10.4	2.4	Unattractive pale flesh, inferior texture, low sugar
Klondike R7	C67-1-5-7-4-10-3, C67-1-5-7-4-10-7, C67-1-5-7-4-10-9 grouped	6	86 per cent resistant	Green	Faint	18.6	678	Excellent	Red	11.2	3.3	Acceptable
Klondike R16	24-31-1-6-3, mixed	5	84 per cent resistant	Dark green	Very faint	19.7	619	Fair	Red	11.0	3.0	Inferior texture
Unnamed	C67-1-5-7-4-10-4 (very similar to Klondike R7)	6	82 per cent resistant	Green	Faint	17.4	639	Excellent	Red	12.0	3.6	Slightly small
Unnamed	Six F_5 selections from 1935 crop (very similar to Klondike R7.)	6	91 per cent resistant	Green	Faint	17.9	668	Excellent	Red	11.4	3.4	Acceptable

R7. Actually the pedigrees of these three F_6 families are as follows: C67–1–5–7–4–10–3, C67–1–5–7–4–10–7, and C67–1–5–7–4–10–9.

A rather complete developmental history of Klondike R7 appears in table 2. Controlled self-pollination was practiced continually, careful and extensive tests proved the soil to be uniformly infested, and complete data were secured for each generation and each plant.

Fruit weights, in all cases, are the average either for the strain or for the plant. Although seed was never saved from open-pollinated fruits, such fruits were harvested, examined, and included in the ratings for individual plants. The fruit-shape index was determined by dividing the polar diameter into the equatorial diameter, as described in a previous paper.[12] A fruit-shape index between 500 and 625 is considered typical and desirable for Klondike. The average fruit-shape index of Klondike R7 in comparison with certain other resistant strains and commercial Klondike is indicated in table 3. Klondike R7 is consistently more blocky, with a higher fruit-shape index, than various susceptible Klondike strains. Other minor differences are also indicated in table 3.

Total soluble solids represent average refractometer readings taken according to the method of Porter and Bisson.[13] Only fully mature fruits were considered. As hundreds of determinations have shown, the refractometric readings are an approximate index of relative sweetness, measured as total sugars. These tests show that a few drops of juice from the center of a mature fruit give practically the same refractometric readings as a composite sample of juice from the entire edible portion. The readings tend, furthermore, to correlate with relative sweetness as determined by the taste of several individuals.

The differentiating characteristics of Klondike R7, Klondike R16, Striped Klondike No. 11, and California Klondike No. 3 are listed in table 3. These four varieties, as a group, are characterized by medium-sized, blocky fruit, rather thin rind, bright-red flesh, relatively high sugar content, and relatively small seeds with seed coats either entirely black or mottled with black, brown, tan, and white in various degrees and combinations. The vines are prolific and vigorous, affording adequate protection against sunburn except under most severe conditions. Klondike R7 apparently matures its fruit a few days earlier than California Klondike, with Striped Klondike usually a few days later than California Klondike.

DEVELOPMENTAL HISTORY OF KLONDIKE R7

Since the entire breeding work beyond the F_1 generation has been conducted on wilt-infested soil, all available data on fruit characters were secured from resistant plants. Adequate check plots planted with commercial Klondike seed proved that the soil both at Lodi and Davis was uniformly and severely infested. Possibly an occasional hybrid plant

Fig. 13.—First harvest of resistant strain C67–1–5–7–4 at Davis in 1934. There were twenty-one marketable fruits from ten plants. The progeny of plant 10 of this strain was named Klondike R7.

escaped infection. Any reference to acceptable or undesirable fruit type is made with Klondike as the standard.

F_1 (C67), grown in the greenhouse at Davis in the winter of 1930–31, yielded no data on resistance, since resistance is a recessive character and since the F_1 must be grown in disease-free soil.

F_2 (C67–1), grown at Lodi in 1931, showed a resistance of 20.3 per cent. The type was variable.

F_3 (C67–1–5), grown at Lodi in 1932, had a resistance of 56.1 per cent; a fruit weight of 21.6 pounds; a fruit-shape index of 633; lacked uniformity with respect to fruit shape or size; and had skin color only slightly variable, resembling Klondike and Tom Watson but not Iowa Belle. Deformed, unsymmetrical fruits appeared abundantly in one of the three replications grown in heavy soil, but were less noticeable in more sandy soil. Many fruits of acceptable exterior appearance were decidedly inferior when cut. Plant 7 was outstanding. Whereas the strain rating was 1.8, plant 7 scored 3.1 because of desirable type, size, and quality.

F_4 (C67–1–5–7), grown at Lodi in 1933, had a resistance of 63.4 per cent. The fruit weight was 16.4 pounds; the fruit-shape index, 587. The strain uniformly resembled Klondike in fruit shape and skin color, with few fruits bearing the slight sutures and scaly rind common to Iowa

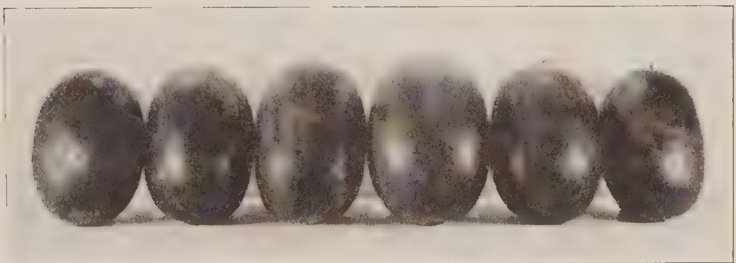

Fig. 14.—Characteristic fruits of the wilt-resistant watermelon Klondike R7. The average fruit weight is 18.6 pounds; the fruit-shape index, 675; and soluble solids 11.2 per cent.

Belle. It was outstandingly uniform for symmetrical fruit type. The quality, though variable, was as near a Klondike as were any strains in the trial. The strain rated 2.1; plant 4, scoring 4.0, was apparently a true Klondike. The soluble-solid content was on a par with Klondike.

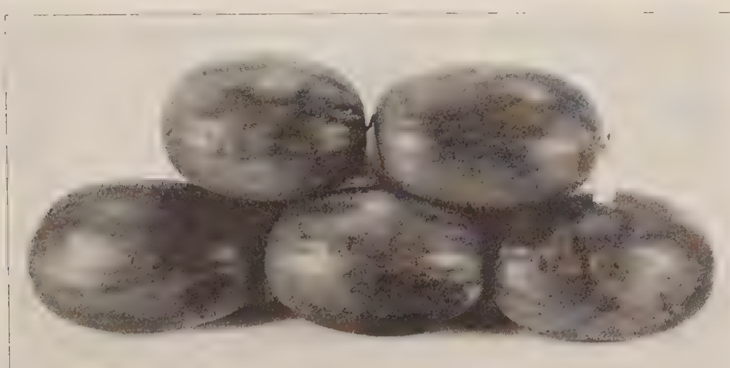

Fig. 15.—A resistant strain of Klondike R7 selected for more oblong fruit shape. (Compare with Klondike R7, figure 14.)

F_5 (C67–1–5–7–4), grown at Davis in 1934, had a resistance of 83.6 per cent. The fruit weight was 21.4 pounds; the fruit-shape index, 615. This was the largest-fruited strain in the trials. The type was not entirely fixed, varying in shape index (per plant) from 581 to 660. The strain appeared relatively homozygous for Klondike sutures, skin color, and size (fig. 13). The flesh of a few fruits was somewhat pale in color

but uniformly high in soluble solids, averaging 11.7 and fluctuating from 10.8 to 13.4. The strain rated 2.9, plant 10 scoring 4.0. Three plants tested above 12.0 per cent soluble solids.

F_6 (C67–1–5–7–4–10), grown at Davis in 1935, had a resistance of 87.1. The fruit weight was 19.0 pounds; the fruit-shape index, 619. The strain was apparently ready for release. It appeared homozygous for exterior and interior fruit characters. The strain rated 3.1; and plants 3, 7, and 9 scored 3.6, 3.4, and 3.5 respectively.

F_7 (C67–1–5–7–4–10, plants 3, 7, and 9) was grown at Davis in 1936. The resulting seed crop was released as Klondike R7. For these three strains the fruit-weight average was 18.6 pounds; and the fruit-shape index was 675, significantly more blocky than commercial or California Klondike (fig. 14). The strain showed only slight variation in fruit type, symmetry, skin color, rind thickness, flesh color, sugar content, and flesh texture. It was slightly less "explosive" than the susceptible Klondike. Average rating for the three strains was 3.1, but a few plants scored 4. The average soluble-solid content was 11.2 per cent. Further work will determine whether this variety can be improved (fig. 15).

COMPARATIVE TRIALS WITH COÖPERATORS

Many California growers and seedsmen have been eager to test resistant varieties developed in other districts and have also assisted in testing the resistant hybrids and selections developed at this station. This plan afforded ample opportunity to observe resistant stocks under a wide variety of soil and environmental conditions and to profit from the counsel of many individuals who have for years been growing watermelons in California. These contacts have been invaluable in connection with the breeding program.

Because of the high quality of Klondike and the anticipated development of resistant types resembling it, information was secured on response, adaptability, and market fitness in other watermelon districts. Disease-resistant varieties should, if possible, be equal in quality to standard susceptible types. It is less important that resistant and susceptible strains of similar varietal characteristics be of identical type; in fact, slight differences might prove helpful in detecting mixtures, besides serving to characterize the new variety.

Seed of Pride of Muscatine, Iowa Belle, and Iowa King was supplied to twenty-one growers for trial on infested soil in 1931. The tests were conducted to determine whether these varieties would maintain their wilt resistance in California and whether they would prove desirable in type, yield, and quality under arid climatic conditions. Grown at both

Davis and Lodi in 1930, they had proved adequately resistant. The 1931 trials resulted as follows: Resistance was well demonstrated, but type and quality were unsatisfactory in comparison with not only Klondike but with Kleckley Sweet. Iowa King and Iowa Belle decidedly lacked sales appeal because of unattractive skin color, thick rind, and low quality represented in terms of coarse flesh texture, pale flesh color, and low sugar content measured only by taste. According to the tests of 1930 and 1931 these varieties, even though resistant, would probably never prove popular in California; and resistant strains resembling Klondike were needed to combat wilt.

Coöperative trials in 1932 were limited. A few growers were still interested in further tests of Pride of Muscatine, which again proved resistant but inferior in quality. Breeding work was in progress at Davis and Lodi, where the F_2 of many crosses was grown and where resistant Klondike plants were sought.

There was no demand for Pride of Muscatine in 1933. Progress of the breeding work is described elsewhere. Breeding stock supplied by Dr. M. N. Walker of Florida, though resistant at Lodi, was not of acceptable fruit type for California.

Trials in 1934 were confined to tests at Davis and Lodi in connection with the breeding work. In type and quality, hybrids of Iowa Belle greatly surpassed those involving either Pride of Muscatine or Iowa King. Resistant selections from both Klondike and Grey Monarch appeared promising.

Besides the usual trials at Davis and Lodi, an extensive planting was made in 1935 at Meloland, a substation of the California Agricultural Experiment Station near El Centro in the Imperial Valley. This planting served a two-fold purpose: first, to study the response of breeding stock under Imperial Valley conditions; second, to secure the opinion of the growers in the Valley. Data covering this trial are presented in table 4. Each strain was replicated once in lots of twenty plants each.

The strains listed in table 4 represent only half of those tested. Many hybrids involving Pride of Muscatine and Iowa King are omitted, only the more promising being listed. These and additional strains involving these two varieties were extensively tested at Lodi, Davis, and Meloland from 1932 to 1936 inclusive. Without exception they proved inferior to the Iowa Belle hybrids. Usually they manifested inferior flesh color and texture, low sugar content, and thick rinds. There has been no opportunity to study the possible genetic linkage of the factors governing inferior flesh quality and resistance manifested by these two varieties. It may be fortunate that Iowa Belle is relatively high in sugar content.[13, 14]

TABLE 4

RESPONSE OF WILT-RESISTANT WATERMELON STRAINS AT MELOLAND, 1935

Pedigree	Parents	Number of generations inbred	Fruit characters: Average weight, pounds	Fruit-shape index	Flesh texture	Flesh color	Soluble solids, per cent	Rating score: Of strain	Rating score: Of parent plant of strain	Comment, particularly defects in comparison with acceptable Klondike
C62-2-1-6-3	Pride of Muscatine × Klondike	5	18.0	485	Fair	Pink	11.3	2.1	3 4	Inferior flesh color and texture
C62-3-6-1-2	Pride of Muscatine × Klondike	5	17.5	649	Fair	Pink	10 2	2.6	3.6	Low in sugar; inferior texture and flavor
C81-2-4-5	Iowa King × Klondike	4	15 6	556	Poor	Pink	9.2	1 5	2.5	Small; poor in flavor; low in sugar
C82-2-2-3	Iowa Belle × Klondike	4	17 5	726	Poor	Pink	11 1	1 5	3 0	Inferior type; poor in texture and flavor
C67-1-6-6-3-2	Iowa Belle × Klondike	6	13 6	678	Fair	Red	10 7	2.1	3.5	Small; inferior in texture
C67-1-8-8-2-4	Iowa Belle × Klondike	6	20 9	591	Good	Red	9.6	2 3	4 0	Low in sugar; inferior in texture
C67-1-5-7-3-2	Iowa Belle × Klondike	6	16 6	699	Good	Pink	10 2	2 3	3 0	Small; low in sugar
C67-1-5-7-3-5	Iowa Belle × Klondike	6	16.2	566	Fair	Pink	10.2	2.7	2.6	Inferior in texture; small
C67-1-5-7-4-1	Iowa Belle × Klondike	6	14.6	638	Excellent	Red	10.3	3.4	4.0	Small; low in sugar
C67-1-5-7-4-5	Iowa Belle × Klondike	6	19.7	698	Good	Pink	11.1	2 3	2.5	Low weight considering size
C67-1-5-7-4-7	Iowa Belle × Klondike	6	15.9	686	Excellent	Red	11.1	2.9	4.0	Small; inferior in flavor
C67-1-5-7-4-8	Iowa Belle × Klondike	6	21.0	621	Excellent	Red	11.4	3 3	3 2	Entirely acceptable and prolific
C67-1-5-7-4-9	Iowa Belle × Klondike	6	18.5	697	Excellent	Red	12.0	3.6	3.5	Entirely acceptable; high in sugar
C67-1-5-7-4-10	Iowa Belle × Klondike	6	18.3	648	Excellent	Red	11.7	3.6	3.8	Entirely acceptable
C67-1-5-7-4-11	Iowa Belle × Klondike	6	20.8	599	Excellent	Red	11.1	3.5	2.5	Acceptable; less blocky than the average
C67-1-5-7-4-12	Iowa Belle × Klondike	6	17.9	622	Good	Pink	10.0	3.0	3.0	Low in sugar; inferior in flavor
C67-1-5-7-6-3	Iowa Belle × Klondike	6	19.0	615	Fair	Pink	11.5	2.7	2.5	Pale flesh of inferior texture
C67-1-3-3-1-7	Iowa Belle × Klondike	6	21.6	670	Poor	Pink	10.4	1.8	2.5	Inferior in texture; low in sugar
C67-1-3-3-8	Iowa Belle × Klondike	5	16.3	671	Poor	Pink	9.1	1.9	2.2	Inferior in texture; low in sugar
C67-1-5-7-20	Iowa Belle × Klondike	5	22.0	623	Good	Red	8.5	1.6	2.5	Inferior in flavor; low in sugar
24-31-1-4-3	Klondike selection	5	19.6	637	Poor	Red	10.9	2.2	3.5	Hard flesh; inferior flavor
24-31-1-6-7	Klondike selection	5	18.0	663	Poor	Red	10.9	2.1	3.1	Hard flesh; inferior flavor
24-31-1-6-10	Klondike selection	5	21.2	659	Poor	Red	10.8	1.8	3.0	Hard flesh; inferior flavor
24-31-1-8-3	Klondike selection	5	18.9	648	Poor	Red	9.8	1.1	4.0	Hard flesh; inferior flavor; low in sugar
California Klondike No. 3*	Susceptible check	10	17.1	598	Excellent	Red	11 9	3 5	4 0	Tender rind, but acceptable
Striped Klondike No. 11*	Susceptible check	4	23 2	581	Excellent	Red	12 5	3 7	4 0	Entirely acceptable

* Soil not infested; hence susceptible checks could be used for comparison.

The test summarized in table 4 was not conducted on wilt-infested soil—first, because such soil was not available at Meloland; second, because if these strains had been exposed to infection there would have been no opportunity for quality comparisons with California Klondike or Striped Klondike. The relative resistance of the more promising strains was, furthermore, determined at Davis.

The first point of interest appears in the column showing the average fruit weight. Seventeen of these strains produced fruits as heavy as California Klondike or heavier. As previously indicated by the writer,[12] inbreeding in Klondike watermelons does not significantly reduce the fruit weight. If, in a certain inbred strain, fruit weight is lowered, usually the number of fruits per plant is increased, so that total plant yield often equals that of the original variety from which the inbred strain was isolated.

With respect to relative vigor few significant variations were discernible. The Iowa Belle vine is much less vigorous than that of Klondike; but these strains represent conscious selections, not only for fruit type and quality but also for vine vigor of Klondike. As has also been shown,[12] inbreeding in Klondike does not lessen plant vigor.

Fruit-shape index, however, varied considerably both among strains and within an individual strain even in the sixth generation from the cross. Unpublished data indicate a rather complex mode of inheritance of fruit shape. Furthermore, the fruit-shape index of the original plant of Iowa Belle used in producing C67 was 818 (oval); that of the F_1 fruit, 829. The parent Iowa Belle plant was heterozygous for fruit shape, as observed in future generations. The male parent, produced by commercial seed and doubtless heterozygous for fruit shape, manifested a fruit-shape index of 548, considered acceptable for this variety.[12]

Considering the final rating score, the hybrid series C67–1–5–7–4 (plants 8 to 10 inclusive) appeared most valuable. The fruit-shape index of these three strains was 621, 697, and 648, respectively, representing fruits more blocky than Klondike but acceptable in type. As mentioned elsewhere, strain C67–1–5–7–4–10 (plants 3, 7, and 9) was the foundation stock for Klondike R7.

Flesh quality is measured by texture, color, sugar, and flavor variations. The three strains involving Pride of Muscatine or Iowa King as the resistant parent were consistently inferior in texture; all except C62–2–1–6–3 were low in sugar; and all had inferior flavor. Of seventeen strains involving Iowa Belle, only four were considered acceptable in flesh quality. Although quality variations among individual plants of these four strains were evident, relatively few were objectionable in

comparison with susceptible Klondike. In these four strains, C67–1–5–7–4–10 (plants 8 to 11 inclusive), the total per cent soluble solids was 11.4, 12.0, 11.7, and 11.1, respectively. California Klondike and Striped Klondike averaged 11.9 and 12.5 respectively. Crosses have been made between Striped Klondike and strain C67–1–5–7–4–10 to produce a sweeter, resistant green-skinned type and a resistant striped type.

The rating scores are interesting when the score of the parent F_4 plant is compared with the F_5 population that it produced; note this condition among the Klondike selections of the 24–31–1 group. Among these four strains the parent-plant ratings were 3.5, 3.1, 3.0, and 4.0 respectively. The soluble-solid percentages of the parent plants were 11.6, 11.9, 11.5, and 11.6 respectively; and the only defect was inferior flesh texture—that is, a texture somewhat hard, though not particularly fibrous, more like that of an apple than of an acceptable Klondike watermelon. In shipping quality the rind of the 24 family surpasses that of the C67 strain. Largely for that reason, in addition to attractive flesh color, these strains of the 24 family are being inbred further. As indicated elsewhere, the most promising strain of the 24 group has been named Klondike R16 but has not been released. It has responded favorably in Florida and Georgia.

The rating score of strain 24–31–1–4–3 dropped from 3.5 to 2.2; of 24–31–1–6–7 from 3.1 to 2.1; of 24–31–1–6–10 from 3.0 to 1.8; and of 24–31–1–8–3 from 4.0 to 1.1. Individual resistant plants of 24–31–1–6–10 at Davis in 1935 again rated high; their performance is reported later.

Trials were much more extensive in 1936 than in 1935. Seed was placed with growers and seed companies to determine resistance and local adaptation as well as opinion regarding the relative merit of the various strains. The arbitrary numbers assigned for the year 1936 do not refer to new resistant varietal numbers. They are used merely to simplify tabulation and represent the following pedigrees:

No. 2: 24–31–1–6 (plants 1, 2, 3, 8, and 11 grouped) is essentially the variety, Klondike R16, named but not yet released. More recent selections within this variety appear to possess higher quality than No. 2. The seed crop was produced in artficially infested soil in 1935.

No. 3: C67–1–3–3–1 (plants 1, 2, and 4) and C67–1–3–3 (plants 4, 6, and 7) mixed is essentially the variety Klondike R19, named but not yet released. It is characterized by oblong fruit type, thick and tough rind, but with flesh quality inferior to that of Klondike R16. It might be a valuable shipping type in districts where

Tom Watson and Thurmond Grey are used. The seed crop was produced in disease-free soil in 1935.

No. 4 : C67–1–5–7–4 (plants 4, 6, and 7) is similar to but not identical with Klondike R7. The seed crop was produced in naturally infested soil in 1935.

No. 5 : C67–1–5–7–12 is similar to but not identical with Klondike R7. The seed crop was produced in disease-free soil in 1934.

No. 6 : C67–1–5–7–14 has the same history as No. 5 but slightly different foundation stock. Seed was produced in disease-free soil in 1934.

No. 7 : C67–1–5–7–4–10 is essentially Klondike R7 (tables 4 and 5). The seed crop was produced in disease-free soil in 1935. This particular strain was exposed to cross-pollination from two volunteer citron plants found about 50 yards from the seed-increase plot in Imperial Valley late in 1935. The per cent contamination is discussed elsewhere in this paper.

These six strains were placed with growers and seed producers in California and with other experiment stations to test for resistance, environmental adaptation, and shipping quality. Seed of these arbitrarily numbered strains was produced either in 1934 or in 1935, each strain in separate isolated areas to prevent cross-pollination.

In three different locations in the Imperial Valley, No. 7 was outstanding because of superior quality. No. 2 produced an extremely vigorous vine, uniformly smooth fruits, and high yield; but although the thin rind was tough, the flesh was applelike in texture. No. 3 had no value except for its thick, tough rind. In one trial in the San Fernando Valley the flesh of No. 2 was less objectionable, and the rind of No. 7 was reported tender. At Merced the texture of No. 2 was inferior, whereas No. 7 was acceptable for local market or for shipping, being of high quality. At Keyes (Stanislaus County), No. 7 manifested superior quality; but the rind seemed somewhat too tender for shipping. No. 2 was tough-rinded, but the flesh again inferior. Resistance to wilt was well demonstrated in all localities. Other tests were conducted at Rio Oso, Gridley, Winters, Waterman, Arlington, and Turlock. The comparative response was much the same, and resistance was maintained.

Besides these six strains representing bulk seed produced in isolated districts during 1934 and 1935, self-fertilized seed from resistant plants in 1935 was planted at both Davis and Meloland in 1936. Data covering these two trials are presented in table 5. Wilt-infested soil was used at Davis; disease-free soil at Meloland.

TABLE 5

RESPONSE OF WILT-RESISTANT WATERMELON STRAINS AT DAVIS AND MELOLAND, 1936

Pedigree	Place	Per cent survival*	Fruit characters: Average weight, pounds	Fruit-shape index	Flesh texture	Flesh color	Soluble solids, per cent: Of strain	Soluble solids, per cent: Of parent plant of strain	Rating score: Of strain	Rating score: Of parent plant of strain	Comments, particularly with respect to defects in comparison with acceptable Klondike
C67-1-5-7-3-5-2	Davis	80	16.9	646	Good	Red	11.2	11.4	2.8	4.0	Tender rind
C67-1-5-7-3-5-2	Meloland		16.8	656	Excellent	Red	11.8	11.4	3.0	4.0	Tender rind
C67-1-5-7-4-1-10	Davis	86	18.3	668	Good	Red	10.9	13.8	3.0	3.5	Acceptable
C67-1-5-7-4-1-10	Meloland		19.0	667	Excellent	Red	12.0	13.8	3.3	3.5	Acceptable; variable in size
C67-1-5-7-4-6-1	Davis	89	18.6	673	Good	Red	11.6	12.6	3.0	3.5	Size too variable
C67-1-5-7-4-6-1	Meloland	..	17.9	664	Excellent	Red	11.9	12.6	3.2	3.5	Size too variable
C67-1-5-7-4-6-3	Meloland		21.0	614	Fair	Pink	11.1	11.9	2.0	3.5	Inferior texture; streaked flesh
C67-1-5-7-4-6-4	Meloland		18.1	631	Excellent	Red	11.8	12.2	2.3	3.3	Exceedingly explosive
C67-1-5-7-4-6-8	Davis	95	23.1	666	Excellent	Red	11.3	12.2	3.0	3.5	Entirely acceptable
C67-1-5-7-4-6-8	Meloland		20.6	608	Excellent	Red	11.7	12.2	3.8	3.5	Entirely acceptable
C67-1-5-7-4-7-12	Davis	92	18.7	648	Good	Red	11.4	13.2	3.1	4.0	Inferior texture
C67-1-5-7-4-7-12	Meloland		17.1	634	Excellent	Red	11.8	13.2	3.3	4.0	Acceptable
C67-1-5-7-4-10-3	Davis	83	18.6	718	Excellent	Red	11.2	12.6	3.3	3.5	Acceptable; slightly oval
C67-1-5-7-4-10-3	Meloland	.	18.1	708	Excellent	Red	12.3	12.6	3.4	3.5	Entirely acceptable
C67-1-5-7-4-10-6	Meloland		16.2	653	Excellent	Red	12.5	11.2	3.2	4.0	Small
C67-1-5-7-4-10-7	Meloland		17.3	643	Excellent	Red	11.5	11.6	3.4	3.8	Entirely acceptable
C67-1-5-7-4-10-9	Davis	90	18.2	678	Excellent	Red	10.9	11.5	3.3	3.5	Entirely acceptable
C67-1-5-7-4-10-9	Meloland		17.9	676	Excellent	Red	11.9	11.5	3.8	3.5	Entirely acceptable
24-31-1-4-3-9	Davis	71	20.4	581	Poor	Pink	10.3	11.2	2.2	3.5	Inferior texture; unsymmetrical
24-31-1-4-3-9	Meloland		21.5	569	Poor	Pink	10.9	11.2	2.4	3.5	Inferior texture; unsymmetrical
24-31-1-6-3-7	Davis	87	17.7	637	Fair	Pink	10.9	11.1	2.5	4.0	Inferior texture; unsymmetrical
24-31-1-6-3-7	Meloland		23.2	582	Fair	Pink	12.0	11.1	2.8	4.0	Inferior texture
24-31-1-6-3-10	Davis	85	24.0	599	Good	Red	11.1	12.8	2.9	4.0	Inferior texture
24-31-1-6-3-10	Meloland		20.3	569	Fair	Red	11.3	12.8	3.0	4.0	Inferior texture
California Klondike No. 3	Davis	.	18.2	587	Excellent	Red	11.1	11.4	3.5	4.0	Tender rind but acceptable
California Klondike No. 3	Meloland	.	17.4	574	Excellent	Red	11.3	11.8	3.5	4.0	Tender rind but acceptable
Striped Klondike No. 11	Davis		23.8	601	Excellent	Red	11.5	12.3	3.6	4.0	Entirely acceptable
Striped Klondike No. 11	Meloland		23.3	581	Excellent	Red	11.6	12.3	3.8	4.0	Entirely acceptable

* See text for discussion of accuracy of the per cent survival. Blank spaces in this column mean that the plants were grown in disease-free soil.

COMPARATIVE RESPONSE AT DAVIS AND MELOLAND IN 1936

Although 20 strains were tested at Meloland, only 14 are listed in table 5; and of these only 6 approximate Klondike quality. Plants 3, 7, and 9 of strain C67–1–5–7–4–10 were used as foundation stock for Klondike R7. The final rating of these three plants at Meloland was 3.4, 3.4, and 3.7 respectively, comparing favorably with susceptible Klondike. When cut the rind appeared somewhat tougher than Klondike. At Davis these three strains were acceptable in type, quality, resistance, and shipping quality.

In general, identical strains manifested similar response at Davis and Meloland. Since the soil at Meloland was disease-free, a few susceptible plants were doubtless included in computing the data; hence the chance for minor discrepancies. Fruit weight was approximately equal except for strains C67–1–5–7–4–6–8, 24–31–1–6–3–7, and 24–31–1–6–3–10; but there was no observable correlation between fruit weight and locality. For California Klondike No. 3 and Striped Klondike No. 11, in fact, fruit weight may be considered identical in the two trials.

Strains C67–1–5–7–4–6–8 and 24–31–6–3–7, besides differing in fruit weight in the two trials, were also unlike in fruit-shape index. Otherwise there were no significant differences in fruit shape. Dissimilarities in flesh texture, flesh color, total soluble solids, and final rating were seldom evident. Apparently, therefore, the response of watermelons at Davis is what may be expected in the Imperial Valley. Strain C67–1–5–7–3–5–2 produced explosive fruit in both trials; and flesh texture of the 24 family was inferior wherever grown, a fact confirming the data secured in 1935 in both localities. Breeding work with the best strains of the 24 family will be continued because some of them are entirely acceptable except for extra-firm texture. In fact, three F_8 plants produced fruits of satisfactory texture at Davis in 1936. The 24 family is characterized by a thin but exceedingly tough rind, admirably adapted to long-distance shipment and to rough handling.

RESPONSE IN IMPERIAL VALLEY IN 1937

In 1937, commercial plantings of Klondike R7 were made by three growers in Imperial Valley, and trial plantings were again made at Meloland in comparison with California Klondike No. 3 and Striped Klondike No. 11.

Klondike R7 was extremely resistant to wilt. Near Brawley, on infested soil, Klondike R7 produced a profitable crop, whereas ordinary Klondike was almost a total loss because of wilt. Many vines of ordinary

Klondike lived long enough to produce fruits, but before they ripened the vines either died or were so severely stunted that foliage protection against sunburn injury was inadequate. As a result, very few fruits were marketable.

Near Holtville, 80 acres were planted with Klondike R7. This crop, on infested soil, yielded in excess of one carload per acre (fig. 16), and even after the second picking the vines remained vigorous, producing a

Fig. 16.—View of a portion of a 40-acre field of Klondike R7 on wilt-infested soil near Holtville in the Imperial Valley in 1937. This crop yielded in excess of 10 tons per acre and the vines remained healthy and vigorous after the second harvest on June 30. (Compare with figure 5.)

third picking of marketable fruits. An excellent yield was also obtained from 60 acres near El Centro and a grower near Calipatria was completely satisfied with his crop.

In these commercial plantings, ample opportunity was afforded to compare Klondike R7 with ordinary Klondike and Striped Klondike. The vines of Klondike R7 were exceptionally vigorous, providing ample protection for the ripening fruits from sunburn injury. Sunburned spots on the fruits soon soften, hence they are valueless and are left in the field. Another character of Klondike R7 doubtless reduces sunburn injury. The fruits are lighter green than those of susceptible Klondike strains and produce a rather heavy "bloom" which doubtless tends to reduce the extent of sunburn injury. The rind of Klondike R7 is tougher than that of the susceptible Klondike strains, which reduces the loss due to breakage. This feature is emphasized by determinations made at Meloland. Growers noted that a carload of Klondike R7, loaded four tiers

high, weighed more than ordinary Klondike, which does well to average 24,000 pounds. Carloads of Klondike R7 weighed from 25,000 to 29,000 pounds. It remains to be determined, experimentally, whether fruit weight of Klondike R7 exceeds that of ordinary Klondike or whether there is a difference in density of fruits of these two varieties. With ordinary Klondike, an average acre-yield of 20,000 pounds in the Imperial Valley is considered profitable. Klondike R7, in 1937, yielded well in excess of this figure.

TABLE 6

Comparative Response of Klondike R7, California Klondike No. 3, and Striped Klondike No. 11 at Meloland in 1937

Variety	Number of plants	Number of fruits per plant	Per cent loss due to sunburn	Per cent loss due to fruit breakage	Average total soluble solids
Klondike R7	132	2.7	8.0	16.8	12.2
Klondike R16	29	1.8	13.8	11.2	12.0
California Klondike No. 3	45	2.4	38.3	26.8	12.2
Striped Klondike No. 11	44	1.9	17.2	16.1	12.7

Careful comparative tests were again conducted at Meloland, with the results appearing in table 6. Klondike R7 compared favorably with the other varieties in total soluble solids, was less subject to sunburn than the others, yielded more fruits per plant and was less subject to breakage than California Klondike No. 3.

COMMERCIAL SEED PRODUCTION OF WILT-RESISTANT VARIETIES

Seed production of wilt-resistant watermelon varieties differs from that of susceptible varieties only in that the resistant varieties are not entirely immune. A strain of Pride of Muscatine, grown continually since 1927 in severely infested soil, was only about 88 per cent resistant at Davis in 1936. As shown by the developmental history of Klondike R7 (table 2), the F_7 generation is only slightly more resistant than the F_5. Though we cannot unreservedly accept the figures denoting survival percentage, we do know that some seedling plants of the various resistant varieties die in infested soil.

If growers, therefore, attempt seed production of resistant varieties in wilt-free soil, certainly some plants originally susceptible will mature a crop and will also cross with plants originally resistant. Because resistance is inherited as a recessive character, any seed from these susceptible plants and any seed of resistant plants that result from fertilization by pollen from these susceptible plants will produce susceptible proge-

nies in the next crop. Thus market growers will receive the impression that resistance is not fixed and that the resistant variety is "going back." Obviously, seed producers should locate infested soil for reproduction of Klondike R7 and of other wilt-resistant varieties.

Given such soil, additional precautions should be considered. *Fusarium niveum* causes seedling rot and damping-off. Seedling rot is most serious at or below 20° C (68° F) soil temperature. To obtain maximum emergence, therefore, one should delay planting until the soil temperature rises to about this point. Seed disinfection, too, will minimize losses from seedling rot. Such chemicals as Semesan Jr. and red copper oxide will prove helpful if dusted on the seeds in a tight container. Excess dust should be removed by screening.

Delaying planting until the soil temperature reaches 25° C (77° F) also results in more rapid infection of really susceptible plants. In the breeding work at Davis, the plants are thinned to three per hill only when the seedlings become crowded. Somewhat later they are thinned to two, and eventually to one. Delayed planting in conjunction with delayed thinning tends to insure a satisfactory stand and to eliminate promptly those plants which are actually susceptible.

The hazard from volunteer watermelon plants and from the inedible citrons should also be considered. To locate infested soil, seed growers naturally search for land where the wilt disease has recently been serious. In most seed-producing districts in California and the southeastern states the soil is not ordinarily subjected to alternate freezing and thawing, and many seeds remain viable until spring. Obviously, volunteer plants from such seed may escape notice in the seed field until fruit setting has begun. Seed growers could profitably locate infested soil at least two years before using it for a watermelon-seed crop.

The writer recently had an unpleasant experience with the citron menace. In July, 1935, after inspecting the resistant strains in the Imperial Valley, he decided to increase the seed supply of C67–1–5–7–4–10 during the remainder of the 1935 growing season in order to provide foundation stock for seedsmen and trial lots for growers for the 1936 crop. To find adequate isolation in an area where frost would not be expected before November 15, he planted seed of this strain early in August, in an isolated district in Imperial Valley. Just after the plants began to blossom, two citron plants were discovered near the seed plot. These were destroyed; but since they had set fruit their pollen might have been carried into the watermelon plot. The watermelon seed was harvested, however, and was planted in several localities in California in 1936. In a 20-acre field in Imperial Valley, one-third of one per cent

of the plants produced citron fruits. Among forty plants at Meloland, one produced citrons; and among eighty plants at Davis one citron was found. At Gridley and Modesto, citron contamination was evident.

Since the two original citron plants in Imperial Valley were at least 50 yards from the watermelon-seed field and since cross-pollination doubtless occurred rather promptly after the flowers opened, it is evident that seed growers should exercise extreme caution in selecting watermelon-seed fields and should destroy wild citron plants before they blossom.

One other aspect of seed production will interest the seed grower. Frequently frost kills plants in the fall, leaving many immature fruits. Is the seed in such fruits viable, and will it produce seedlings as vigorous as seed from vine-ripened fruits? During 1933 to 1935 inclusive, fruits were picked when 10, 15, 20, 25, 30, 35, 40, 45, and 50 days old. All were held at room temperature for approximately two months, when seed was extracted separately from each fruit and tested for viability. Seed from fruits picked when 15 days old germinated as well as that from vine-ripened fruit. Some seed from the 10-day fruits germinated, but the quantity and percentage were so small that it would be impractical to use them. Average fruit weights for 10, 15, 20, 25, and 45-day fruits of Klondike in 1935 were about 3, 5, 11, 13, and 18 pounds respectively.

FUTURE DEVELOPMENTS IN WATERMELON BREEDING

At present California growers seem satisfied with Klondike R7. Typically the fruits are more blocky than either California Klondike No. 3 or commercial Klondike, and the skin suture is less pronounced. The rind, though somewhat tender, is probably as thick and as tough as commercial Klondike, a variety shipped successfully from California for many years. Slight difference in type and less distinct sutures differentiate fruits of Klondike R7 from susceptible Klondike strains, and skin color seems somewhat lighter green. The fruit shape of Klondike R7 is not yet a fixed character. Future selections may result in strains more oblong in shape, although Klondike R7 is entirely acceptable.

By crossing Klondike R7 with the most desirable strains of the 24 family, breeders should be able to develop a variety with the tough rind of selection 24 and the quality of Klondike R7.

Crosses of Klondike R7 with Striped Klondike No. 11 should result in a sweeter Klondike R7 with a tougher rind and also in a wilt-resistant Striped Klondike.

From the present collection of resistant types of diverse fruit characters one should be able to develop resistant varieties suited to culture in the various watermelon-producing districts of the United States. Before

undertaking such work one should carefully consider the advisability of adding new resistant varieties. At least, all existing varieties should first be carefully tested. Possibly growers and shippers would prefer to change watermelon types rather than to develop resistant strains of susceptible varieties now popular in trade channels. New varieties must meet some well-defined need. Possibly more careful handling methods would extend the production of such resistant varieties as Klondike R7. The modern trend seems toward smaller-fruited types with thinner rinds than Tom Watson and Thurmond Grey. Quality need not be sacrificed for large fruit size.

SUMMARY

Seven watermelon varieties—five developed in Iowa and one each developed in Florida and Australia—were resistant to wilt (*Fusarium niveum*) when grown in California. None of these manifested acceptable type or quality under California conditions. The need for resistant types for California is indicated.

Demonstrably, the genes for resistance are carried by the commercial, susceptible varieties Klondike and Grey Monarch. Continued propagation of resistant stock of these varieties, with complete control of self-pollination, has resulted in new varieties resistant enough to produce profitable crops on severely infested soil. The Klondike selection named Klondike R16 has not yet been released, being inferior in quality to Klondike R7, described herein.

Hybrids of Klondike with either Pride of Muscatine or Iowa King have proved decidedly inferior to hybrids resulting from crosses of Iowa Belle with Klondike—inferior because of thick rinds, pale red or pink flesh, undesirable flesh texture, and relatively low sugar content.

Klondike R7, the new resistant variety, was released in February, 1937. At that time it represented the F_7 generation of cross 67 obtained in 1930 by crossing Iowa Belle with Klondike. This new variety differs from commercial Klondike in fruit type, skin sutures, skin color, and reaction to *Fusarium niveum*. It is recommended for any district where Klondike has proved adapted.

A brief history is given of the development of wilt-resistant watermelon varieties, showing that the genes for resistance are carried by the commercial varieties Kleckley Sweet, Dark Seeded Grey Monarch, White Seeded Grey Monarch, and Klondike. Resistance manifested by Iowa Belle, Iowa King, Conqueror, and Klondike R7 is traced back to the stock citron, used by W. A. Orton early in the twentieth century in developing resistance to *Fusarium niveum*. Improved Stone Mountain No.

5 obtained its resistance from Japan No. 7, a white-fleshed but edible variety secured from Japan in 1927.

The value of the refractometer in connection with breeding work is indicated. Likewise, numerical values of shape indices have been found useful.

Since the successful commercial production of seed of resistant varieties involves thorough understanding of *Fusarium niveum* and its host relationships, the latter are discussed in detail. Precautions are indicated for the benefit of seed producers.

There is a definite need for more refined technique in determining accurately the relative resistance of varieties and hybrid material. Until some such technique is developed, results of greenhouse indexing trials, determination of physiological specialization, and studies on inheritance of resistance are of questionable value.

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